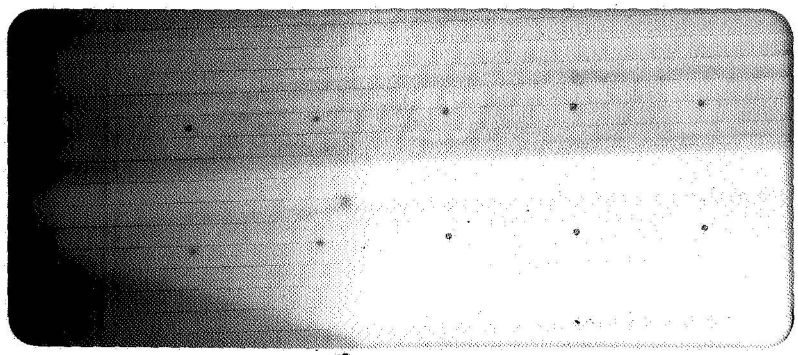

ENGINEERING PLANNING DOCUMENT

JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CALIFORNIA

ENGINEERING PLANNING DOCUMENT

SPACE FLIGHT OPERATIONS

MEMORANDUM

RANGER IV

EPD-91

5 JULY 1962

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I. INTRODUCTION

A. Purpose

The Space Flight Operations Memorandum summarizes, on the basis of the information available at this time, the following:

1) Performance of the space flight operations complex.

2) Performance of the various tracking facilities involved.

3) Analysis of the telemetry data received.

4) Performance of the spacecraft.

5) Orbital data.

B. Summary

The space flight operation for Ranger 4 began at approximately 1700, 23 April 1962 GMT when communications were established between the Space Flight Operations Center, Pasadena, the Deep Space Instrumentation Facility (DSIF), and the Atlantic Missile Range (AMR). Liftoff of the launch vehicle occurred at 205015.04, 23 April 1962 GMT, and injection of the spacecraft into a Moon intercept trajectory occurred at 210414.6 GMT.

The AMR tracking stations and the Launch Checkout Telemetry Trailer (LCTT) tracked the spacecraft after liftoff and received good data. The first DSIF station to acquire Ranger IV was DSIF 1, the Mobile Tracking Station (MTS). From the spacecraft signal and subcarriers they acquired, it was apparent that the spacecraft data encoder commutator had stopped. The DSIF tracked the spacecraft transponder signal until the batteries supplying power to the transponder were exhausted at 10 hours 32 minutes after launch. The DSIF then tracked the Capsule signal until the spacecraft passed behind the Moon. Lunar impact occurred approximately 64 hours after launch.

The only telemetry information recovered from the Ranger IV mission was received by the AMR tracking network and by the LCTT. The failure in the spacecraft precluded the recovery of any scientific data.

During the period that the LCTT was tracking the spacecraft, no abnormalities were observed and telemetry data indicated that the spacecraft was operating normally. When DSIF 1 acquired the spacecraft transponder signal at about L + 25 minutes, it was apparent that a failure had occurred in or had affected the Central Computer and Sequencer. Later in the mission, attempts were made to transmit commands to the spacecraft for troubleshooting purposes. Since these attempts met with no success, it was not possible to initiate the midcourse and terminal maneuvers.

Seven orbits were computed during the Ranger IV space flight operation. These orbit computations were used to provide pointing information for the DSIF and for impact prediction.

Ranger IV impacted the far side of the Moon at 124930, 26 April 1962 GMT. The Capsule signal was lost two minutes earlier as the spacecraft went behind the Moon. Space flight operations were continued to confirm that the spacecraft did not reappear from behind the Moon. With no signal having been detected, these operations were discontinued at 1330, 26 April 1962 GMT.

II. SPACE FLIGHT OPERATIONS COMPLEX

The space flight operations complex completed all required operations with no difficulty. All orbit computations were completed approximately on time with one exception, the first orbit computation. This orbit was intended to provide pointing data for the DSIF; however, DSIF 1 acquired the spacecraft before receiving preliminary orbit predictions.

The inability to command the spacecraft changed the planned methods of formulating commands. Eighteen commands were sent in an attempt to obtain a response from the spacecraft. Since the situation did not require that these commands be transmitted in accordance with normal procedures, they were transmitted from the Space Flight Operations Center to DSIF Control by voice. The spacecraft did not respond to any of the commands. The Command Log for Ranger IV is shown in Table I.

Because of the failure of spacecraft communication, the mode of operation of the Spacecraft Data Analysis Team (SDAT) was changed. The planned mode had been to monitor large quantities of data from the spacecraft. Instead, the SDAT had to attempt to identify the spacecraft failure using the small amount of data acquired prior to injection.

Table I. Command Log

24 April 1962 GMT

Command	GMT Transmitted	GMT Verified	Remarks
RTC-0	015220	015302	
RTC-0	015323	015402	
SC-1	015700	015742	No blips - DSIF 1 saw no change in B-20. B-2-2 blip reported at 020209.* B-2-1 blip reported at 020221.*
RTC-0	021150	021228	
RTC-0	021249	021327	
SC-1	021500	021540	No blips seen.
1st RTC-5	022200	022240	No changes seen in Channels 2 and 8.
2nd RTC-5	022700	022740	Ch. 2=596, Ch. 8=3122, Ch. 1=399.
3rd RTC-5	023300		Out of lock - did not get in.
4th RTC-5	024300	024340	No change.
5th RTC-5	024800	024840	No change.
RTC-0	031500	031540	
RTC-3	031601	031640	No change.
RTC-0	050510	050550	
RTC-0	050611	050650	
RTC-3	051200	051230	No change.
RTC-0	055000	055040	
RTC-2	055200	055240	No change.

* Were found to be false indications.

III. TRACKING FACILITIES

A. General

The facilities tracking Ranger IV were AMR, the LCTT, and DSIF Stations 1, 2, 3, 4, and 5. In addition, several other agencies attempted to obtain optical tracks of Ranger IV while the spacecraft was in the vicinity of the Moon.

AMR was assigned the responsibility of providing JPL with 1) orbital elements of the parking and transfer orbits; 2) acquisition information for DSIF 1 (MTS), DSIF 4 (Woomera), and DSIF 5 (Johannesburg); and 3) the raw data that would be used by JPL to provide a backup to the computation of the transfer orbit. AMR instrumentation performed satisfactorily with all stations (except Puerto Rico) acquiring the spacecraft normally.

B. Liftoff to Injection

1. AMR Participation in Tracking Ranger IV

a. Uprange (Antigua) Stations

Good data was received from the uprange tracking stations with the exception of Puerto Rico. A network failure caused the data loss at Puerto Rico. Figure 1 shows the AMR tracking network C-band coverage of the Ranger IV mission. The data from the Twin Falls Victory Ship (TFV) was sent to JPL in near-real time and was used to supply quick-look angles for DSIF 4 and 5. AMR had some difficulty in processing the TFV data and, for this reason, the first orbit computation was performed by JPL.

b. Downrange (Ascension) Stations

In general, the data received from Ascension was good. Ascension radar acquired the Agena C-band beacon at L + 1218 seconds, continuing to track (with a 65-second interruption) until the Agena set below the horizon at L + 3355 seconds (see Figure 1). The data from Ascension, sent to JPL in real time, went through six recycles to remove range ambiguities. This data was used to determine the Agena orbit and confirmed that the Agena would miss the Moon. The DSIF-calculated values of residuals showed that the range determined from the Ascension data was off + 5.5 km and the elevation was high by 0.45°. AMR is investigating the possible causes of these ambiguities.

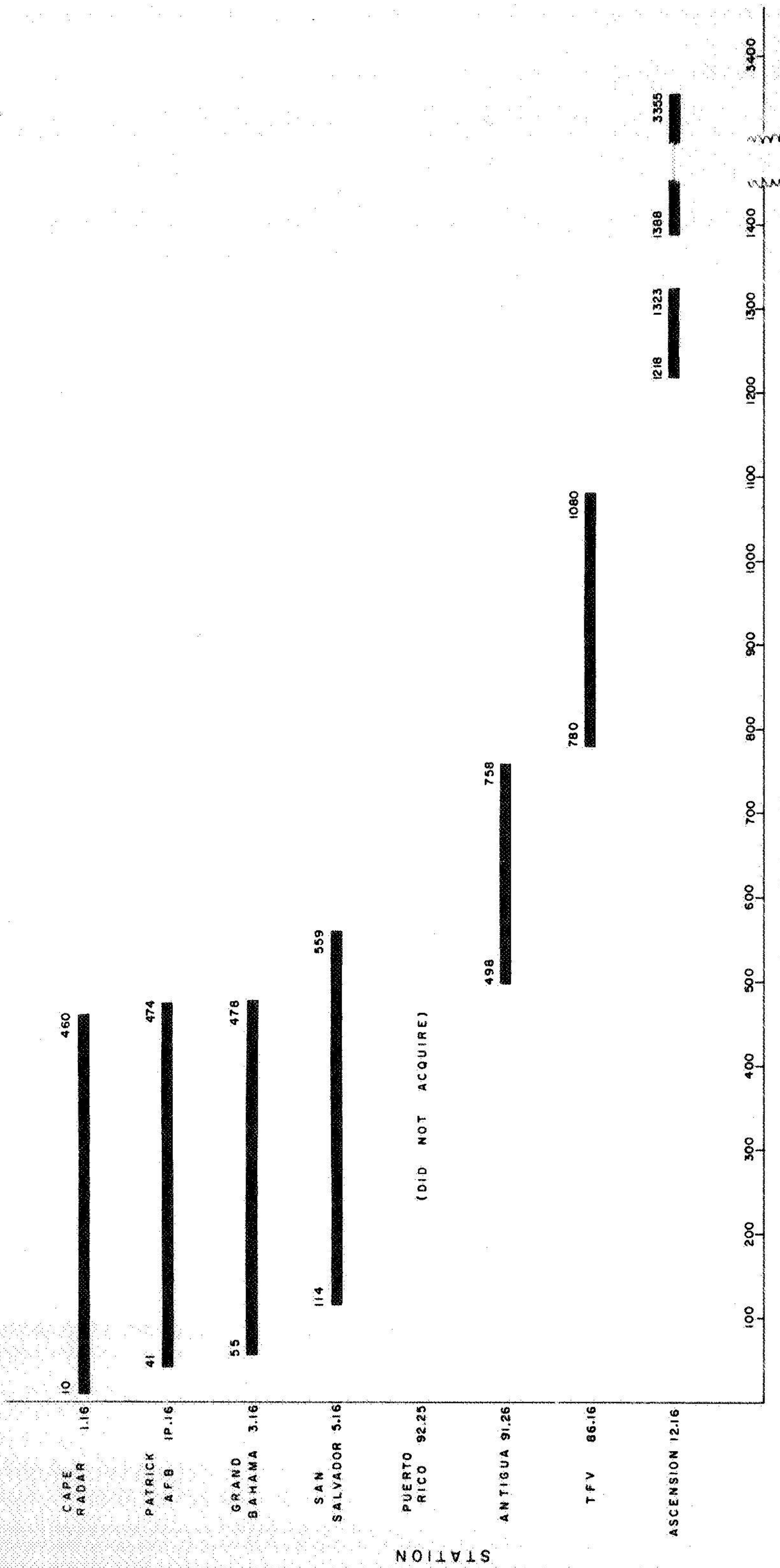

Figure 1. AMR C-Band Radar Coverage, Ranger IV

c. Analysis of TFV Data

The TFV acquired full automatic track at L + 780.55 seconds. The range, at the time of acquisition, was 703 nautical miles and the azimuth angle was 288° 48.2'. Minimum tracking range from TFV was 182 nautical miles, with a maximum antenna elevation of 43° 1.3'. The TFV lost signal at L + 1080.55 seconds at a range of 993 nautical miles.

An orbit was fitted to all data from the TFV and the resulting root-mean-square fit data (observed minus best fit, no mean or systematic errors subtracted) are given in Table II.

Table II. RMS Fit for Twin Falls Victory Ship Data

Range (km)	Azimuth (degrees)	Elevation (degrees)
0.00890	0.0194	0.0194

Orbits derived from data supplied by the DSIF, AMR's Ascension Station, and the TFV are given in Table III.

2. JPL Participation in Tracking Ranger IV

a. LCTT Station

The LCTT acquired the spacecraft transponder signal at launch and lost lock at L + 460 seconds. At the time of loss of lock, the signal strength of the spacecraft transponder was -135 dbm. LCTT data indicated that the spacecraft was functioning normally. Between the time of electrical separation of Agena and Ranger IV (L + 16 minutes 33.2 seconds) and acquisition by DSIF 1, a malfunction within the spacecraft resulted in the loss of Channel 1, the sync pulses on Channel B-19, and commutation on Channels 2, 3, 4, 5, and 6.

Table III. Orbits (True Equator-Equinox of Epoch)

	Semimajor Axis (a)	Eccentricity (e)	Inclination (degrees)	Right Ascension of Ascending Node (degrees)	Argument of Perigee (degrees)	Degrees (+)	Epoch 4/23/62
DSIF	306,545	0.97858823	29.698774	334.8797	146.22976	149.47634	21h04m19s
* Ascension	548,264	0.988	29.776	[illegible]08	146.506	149.424	"
TFV	297,036	0.97790362	29.7186	334.642	146.430	149.709	"

* The orbit shown above for Ascension was still being evaluated at the time of publication of this document.

C. Postinjection

1. General

The DSIF was intended to provide several spacecraft communication capabilities during the Ranger IV mission. All DSIF stations had the capability of recording, on magnetic tape, telemetered information from the spacecraft. DSIF 3 and 5 also had equipment for encoding selected data, comprising telemetry measurements, into a teletype format for transmission back to JPL for near-real time analysis. All stations could provide tracking data consisting of time-labeled pointing angles and doppler frequency. Transmitters at DSIF 1, 3, and 5 would allow more accurate tracking data to be obtained when these stations were able to interrogate the spacecraft transponder. The transmitter at DSIF 3 could also allow desired spacecraft actions to be commanded from the ground. The receiver at DSIF 2 was equipped with a Maser amplifier and a Cassegrain reflection system. This equipment provided this station with the most sensitive listening system in the DSIF net and was intended for use during the Capsule retromaneuver. Because the spacecraft failure severely limited the planned operations, no data were obtained from any of the experiments and no information on how the spacecraft responded to ground commands could be obtained.

2. Launch Phase

DSIF 1 acquired the spacecraft at approximately nine minutes after injection without difficulty (see Table IV). The DSIF net tracked the Ranger IV spacecraft continuously from DSIF 1 acquisition until approximately one minute before lunar impact. Initial detection of the spacecraft transponder signal was made by DSIF 1 at 211312, 23 April 1962 GMT. DSIF 5 first detected the signal at 211422 GMT the same day. By 211706 GMT, both DSIF 1 and 5 were tracking in the one-way doppler mode. At 212918 GMT, the MTS had accomplished two-way acquisition. As soon as successful lock had been established, it became apparent that a spacecraft failure had occurred. Except for Channel 1 (the spacecraft frequency reference channel), all telemetry channels were in lock but no telemetry commutation was occurring. The received signal level was varying considerably. DSIF 1 reported that the signal level at 213428, 23 April 1962 GMT was -125 dbm with an 18 db variation occurring between 213330 GMT and 213510 GMT. DSIF 5 reported at 2205 GMT that the received signal strength was -104 dbm with a variation, in a four-minute period, of 14 db.

No particular difficulty was experienced in tracking during this initial phase. DSIF 4 successfully acquired the transponder signal at 2223, 23 April 1962 GMT, and tracked the spacecraft until 0006, 24 April 1962 GMT. For 20 minutes during the early portion of its tracking period, DSIF 4 tracked the Capsule signal. As in the case of the transponder signal, the Capsule signal was also varying. At 221530, 23 April 1962 GMT, the received Capsule

Table IV. DSIF View Periods

DSIF	ACQUISITION (GMT)	LOSS (GMT)
1	23/2113	24/0719
5	23/2114	24/0843
4	23/2223	24/0006
2	24/0832	24/1703
3	24/0904 (1)	24/1705
4	24/1352	25/0159
5	24/2122	25/0925
2	25/0847	25/1730 (2)
4	25/1423	26/0213
5	25/2140	26/0932
2	26/0846	26/1248 (3)
3	26/0833	26/1248 (3)

NOTES

(1) Initial search for the transponder signal was unsuccessful. No signal present.

(2) Searched for the transponder signal until 25/1748.

(3) Searched for the transponder signal until approximately 1330 GMT. No signal present.

signal strength was -152 dbm with a -5 db variation occurring every 20 seconds. Approximately every 4 1/2 minutes, a variation would occur causing the signal level to drop below the receiver threshold.

At 2305, 23 April 1962 GMT, the DSIF 5 transmitter was turned on and successfully acquired the spacecraft transponder in a two-way lock after the DSIF 1 transmitter had turned off. DSIF 5 tracked in this mode until 2336, 23 April 1962 GMT when its transmitter was turned off. DSIF 1 then reacquired and established two-way lock. Tracking continued in this manner until 000754, 24 April 1962 GMT when DSIF 5 turned on their transmitter and again acquired the spacecraft in a two-way lock. This tracking mode was maintained until 0721, 24 April 1962 GMT when the spacecraft transponder power failed. This was the first operational use of the Johannesburg transmitter, and two-way doppler data were obtained.

3. Midcourse to Terminal Maneuver Phase

Because of the absence of clock pulses to the spacecraft command decoder, it was not possible to perform a midcourse maneuver. During the time after 000754, 24 April 1962 GMT, when DSIF 5 was in two-way lock, various commands were transmitted to the spacecraft. Attempts were made to advance the spacecraft telemetry mode, to switch the transponder signal from the omniantenna to the high-gain antenna, to change the high-gain antenna hinge angle, and to override the spacecraft roll control system. None of these commands was successful (see Table I).

At approximately 0720, 24 April 1962 GMT, the spacecraft transponder signal went to zero due to battery exhaustion. After this time, DSIF 1 continued searching for the transponder signal and DSIF 5 began searching for the Capsule signal. The DSIF 1 search was unsuccessful and at 0835, 24 April 1962 GMT the station was secured. DSIF 5 acquired the Capsule signal at 081430 GMT the same day and tracked it, with intermittent out-of-lock periods, until 084320, 24 April 1962 GMT when the spacecraft set below their horizon.

4. Terminal Phase

A terminal maneuver was not attempted because of inability to establish communication with the spacecraft.

After the disappearance of the transponder signal, the DSIF continued to track the Capsule signal. Searches for the transponder signal were conducted at least once during each station's visibility period but no signal was detected. The Capsule signal level gradually decreased and the variation in level was sufficient to cause intermittent loss of receiver lock.

5. Post-Terminal Phase

Lunar impact was predicted for approximately 1250, 26 April 1962 GMT. During this final period, both DSIF 2 and 3 were tracking the Capsule signal. The signal level was varying at both stations, and receiver lock was being lost every four to five minutes. Capsule signals were finally lost by DSIF 3 at 124747, 26 April 1962 GMT and by DSIF 2 at 124754, 26 April 1962 GMT. This loss of signal occurred as the spacecraft disappeared behind the Moon. DSIF 2 and 3 continued to listen for Capsule signals until 1350, 26 April 1962 GMT. No signals were detected, thereby verifying that the spacecraft impacted the Moon.

IV. TELEMETRY RECOVERY

A. General

Very little spacecraft telemetry was recovered during the Ranger IV mission because of the failure affecting the CC&S. The only recovery was of data recorded by the LCTT from liftoff until the spacecraft set over the horizon, and of spacecraft data recorded prior to electrical disconnect through the Agena telemetry system.

B. Engineering

All Ranger IV telemetry transmission having stopped prior to DSIF 1 acquisition of the spacecraft, no engineering data were recovered beyond that time.

C. Scientific

No scientific telemetry was received from the Ranger IV mission.

V. SPACECRAFT PERFORMANCE

A. General

The performance of Ranger IV can be divided into three phases: launch, midcourse, and terminal. The launch phase was initiated by starting the launch counter in the spacecraft CC&S two minutes before liftoff. It was just after injection, when DSIF 1 acquired the spacecraft transponder signal, that it first became apparent that the data encoder commutator was not running. Subsequent attempts to transmit commands to the spacecraft for troubleshooting purposes met with no success.

B. Launch Phase

While the LCTT was tracking the spacecraft, no abnormalities were observed and telemetry data indicated that the spacecraft was operating normally. The AMR tracking stations also received telemetry data from the spacecraft.

When DSIF 1 acquired the spacecraft transponder signal and the subcarriers at about L + 25 minutes, the data encoder commutator was not running and there appeared to be no 400 cps signal on Channel 1. Since no blips were observed on Channel B-2 at the time when the solar panels were to be extended nor at any of the times when subsequent CC&S commands were to be given, it was concluded that the CC&S was not functioning. At L + 234 minutes, Channel 1 locked on a 400 cps tone. Periodic variations in the received signal strength indicated that acquisition of the Sun had not been accomplished.

The DSIF continued to track the spacecraft transponder signal throughout the launch phase and until L + 10 hours 32 minutes at which time no signal from the transponder could be detected. Since the anticipated life of the transponder battery was about nine hours, it was concluded that the loss of signal was due to battery power depletion.

Plots of received signal strength have been made for ten hours of transponder tracking at DSIF 1 and for one hour at DSIF 4. The peak levels closely match the values predicted for the transponder transmitting in the high-power mode, indicating that the "power up" command was given. Unfortunately, no valid computer plots of DSIF 5 signal strength are available to help corroborate this conclusion.

C. Midcourse Phase

On 24 May 1962 GMT, 18 commands were sent to the Ranger IV in an attempt to obtain some response from the spacecraft. A list of the commands and the times at which they were sent is shown in Table I. The spacecraft did not respond to any of the commands. Therefore, the midcourse maneuver and the scientific experiments planned for Ranger IV were not attempted.

D. Terminal Phase

The Central Computer and Sequencer failure prevented the performance of a terminal maneuver. However, the Ranger IV Capsule signal was tracked until the spacecraft passed behind the Moon.

VI. ESTIMATION OF THE ORBIT

Seven orbits were computed during the Ranger IV space flight operation. The first computed orbit was used to provide early pointing information for the DSIF stations. The next five computed orbits were used primarily for determining accurate target parameters for impact prediction. A seventh orbit was computed, approximately 24 hours after injection, to remove the bias angles and obtain the final impact prediction.

If a midcourse maneuver had been commanded over DSIF 5, it would have been based on Orbit 3; had the maneuver been commanded over DSIF 3, it would have been based on Orbit 4 or Orbit 5 in accordance with the Space Flight Operations Plan, Ranger 4, EPD-74. Errors due to the orbit determination process alone would have been of the order of 80 km at impact, well within the required accuracy but still capable of further improvement as the process is refined.

The postinjection orbit was determined using the JPL Orbit Determination Program (ODP). The orbital parameters and the trajectory characteristics of these orbits are tabulated in Table V for selected trajectory epochs.

The legend applying to Table V follows:

X, Y, Z — Vernal equinox cartesian coordinates in a geocentric equatorial system. The origin is the center of the Central Body. The principal direction ($\vec{X}$) is the vernal equinox direction of date and the principal plane (XY) is the equatorial plane of date. $\vec{Z}$ is along the direction of the Earth's spin axis of date (Kilometers).

$\dot{X}$, $\dot{Y}$, $\dot{Z}$ — First time derivatives of X, Y, and Z, respectively, i.e., cartesian components of the probe space-fixed velocity vector (Kilometers/Second).

For Earth as Central Body

R — Probe radius distance (Kilometers).

ϕ — Probe geocentric latitude (Degrees).

θ — Probe east longitude (Degrees).

v — Probe Earth-fixed velocity (Kilometers/Second).

γ — Pitch angle of the probe Earth-fixed velocity vector with respect to the local horizontal (Degrees).

σ — Azimuth angle of the probe Earth-fixed velocity vector measured east of true north (Degrees).

For Moon as Central Body

R — Probe radius distance (Kilometers).

ϕ — Probe selenocentric latitude (Degrees).

θ — Probe selenocentric east longitude (Degrees).

v — Probe selenocentric-fixed velocity (Kilometers/Second).

γ — Pitch angle of the probe selenocentric-fixed velocity vector with respect to the local horizontal (Degrees).

σ — Azimuth Angle of the probe selenocentric-fixed velocity vector measured east of the Moon's mean spin axis (Degrees).

a	Semi-major axis (Kilometers).
e	Eccentricity.
i	Inclination of the orbit plane to the equatorial plane (Degrees).
Ω	Longitude of the ascending node (Degrees).
ω	Argument of pericenter (Degrees).
ν	True anomaly (Degrees).

Period is measured in seconds, apogee and perigee in kilometers.

Table V. Orbital Parameters of Ranger IV

TIME OF EVENT	EPOCH X R	 Y ϕ	CENTRAL BODY Z θ	 $\dot{X}$ v	 $\dot{Y}$ γ	 $\dot{Z}$ σ	EPOCH OF PERICENTER PASSAGE a e	 i Ω	 ω ν	PERIOD APOGEE PERIGEE
POSTINJECTION ORBIT	4-23-62 21h 04m 19s		EARTH				4-23-62 21h 03m 45.053s			
	-3893.0895 6568.8828	5026.1205 14.574054	1652.9353 320.25897	-8.6979759 10.543285	-4.8240304 1.6687774	-4.5972464 117.27733	306543.84 .97858815	29.698773 334.87970	146.22976 3.2465826	28151.213 606524.01 6563.6685
IMPACT CONDITIONS	4-26-62 12h 50m 00.383s		EARTH							
	149460.51 378795.94	-323786.17 -19.703532	-127712.30 248.23571	-.82511277 27.417922	-1.5337943 2.2259672	-.23562437 270.27416				
			MOON				4-26-62 12h 58m 45.736s			
	1682.6893 1738.0898	-123.21191 -11.965175	-417.53132 231.45130	-1.7580050 2.6692629	-1.9757244 -33.722636	-.33305879 276.41444	-3343.5162 1.3802314	156.86051 211.19802	275.21326 -57.529497	N.A. N.A. 1271.3099